Conference Paper

Long-term Changes in Community of Planktonic Algae of the Northeastern Black Sea (2005-2011)

Olga N. Yasakova[1], Pavel R. Makarevich[2], and Yuri B. Okolodkov[3]

[1]Southern Scientific Centre, Russian Academy of Sciences, Rostov-on-Don, Russia
[2]Murmansk Marine Biological Institute, Kola Science Centre, Russian Academy of Sciences, Murmansk, Russia
[3]Universidad Veracruzana, Instituto de Ciencias Marinas y Pesquerías, Boca del Rio, Veracruz, Mexico

Abstract

Phytoplankton dynamics in bays and open waters of the northeastern Black Sea was studied in 2005-2011. Species composition comprised 11 classes and 210 species including 19 potentially toxic species and 5 new records for the study area. The maximum species richness was found among dinoflagellates (96 species) and diatoms (78); other major taxonomic groups were represented by a small number of species (2 to 10). The highest abundance of planktonic algae was observed in the Novorossiysk port waters (5.1×10^5 cells/ L; 1.08 g/m^3). Algal abundance and biomass in the bays of Anapa, Gelendzhik and Tuapse were 2 to 5 times less than in the bay of Novorossiysk. Small-celled mesosaprobic species of diatoms (*Skeletonema, Leptocylindrus, Thalassionema* and *Chaetoceros*), euglenophyceans (*Eutreptia lanowii*), cyanobacteria (*Lyngbya* and *Oscillatoria*) and mixotrophic dinoflagellates (*Gymnodinium, Heterocapsa, Gyrodinium* and *Prorocentrum*) were found in the bays. Abundance and biomass in the open sea in front of the bays were 1.5-2 times higher than those observed within the bays. The minimum abundance and biomass were observed in the open sea (5.4×10^4 cells/L, 0.28 g/m^3) and the Kerch Strait (9.8×10^4 cells/L, 0.186 g/m^3). In these areas the most significant part of the population (34-40% of phytoplankton abundance) was composed of the nanoplanktonic prymnesiophycean *Emiliania huxleyi*, the large-celled diatoms *Proboscia alata* and *Pseudosolenia calcar-avis* and dinoflagellates of the genus *Protoperidinium* (up to 45% of phytoplankton biomass).

Keywords: planktonic algae, species composition, abundance and biomass, Northeastern Black Sea

Corresponding Author:
Olga N. Yasakova
yasak71@mail.ru

Received: 24 December 2019
Accepted: 9 January 2020
Published: 15 January 2020

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the BRDEM-2019 Conference Committee.

1. Introduction

Planktonic photosynthetic algae are the basis for the food webs in marine ecosystems. The development of organisms of other trophic levels depends on the algal species composition and their abundances. The study of phytoplankton gives an insight into trends of changes in the structure and functioning of coastal ecosystems. Knowledge

How to cite this article: Olga N. Yasakova, Pavel R. Makarevich, and Yuri B. Okolodkov, (2020), ``Long-term Changes in Community of Planktonic Algae of the Northeastern Black Sea (2005-2011)'' in *International applied research conference «Biological Resources Development and Environmental Management»*, KnE Life Sciences, pages 569--580. DOI 10.18502/kls.v5i1.6129

of the state of planktonic algae can be used in environmental monitoring and early diagnostics of the health of a water body [1]. Changes in the qualitative and quantitative composition of phytoplankton are tracked in water subjected to anthropogenic effects, mainly in the form of domestic and industrial discharges. Most often this results in algal blooms, some of which are toxic. In turn, this reduces the recreational value of the Black Sea coast and significantly affects the state of the whole ecosystem. In the shelf zone (including bays) of the Russian sector of the Black Sea the phytoplankton is exposed to negative changes caused by increased levels of eutrophication [2]. Therefore, information about the characteristics of planktonic microalgae in both open coastal waters of the Black Sea and semi-enclosed bay waters of the port cities Novorossiysk and Tuapse and resort cities Anapa and Gelendzhik are of interest. During the 20th century, the study of phytoplankton of the Black Sea has been focused on its northwestern part. The northeastern part of the sea has been much less investigated. The aim of the present study was to determine the taxonomic composition and abundance of planktonic algae in bays and open waters of the northeastern Black Sea (NEBS).

2. Methods and Equipment

2.1. Methods

2.1.1. Diagrammatic representation

Phytoplankton samples were taken from the waters adjacent to the ports of Novorossiysk and Tuapse and the resort cities Anapa and Gelendzhik, and from some offshore stations. Sampling in the bays was carried out during short boat trips in different seasons in 2005-2011 (Figure 1). The seasonal studies of phytoplankton in the open NEBS were a part of expeditions on board the RV "Deneb" in July 2007, April, June and October 2008, April 2009, July 2010 and June 2011. The vertical structure of phytoplankton in the open NEBS was studied water sat standard depths of 0, 5, 10, 20, 30, 40, 50, 100 and 150 m at deep-sea stations; surface and near-bottom samples were taken at shallow sampling stations of the shelf zone of the sea (to 100 m depth) and in the Kerch Strait area.

Phytoplankton was sampled during the day with chemical water-bottles of 1.0-1.5 l capacity. Samples were further concentrated using an inverse-filtration device [3] and nuclepore filters (the pore diameter of 1-2 μm) and were fixed with neutral formalin to a final concentration of 1-2%. To identify species, living cells were also observed before or after filtration, depending on the cell density [4-6]. In total, 1047 samples were analyzed in a Nageotte counting chamber under a LOMO MIKMED-2 microscope (Saint Petersburg, Russia) using the 10/0.30 and 40/0.65 bright-field objectives, in three or more replicates [7]. A species was considered dominant when its abundance in a sample was >20% of the total phytoplankton abundance and subdominant when 10 to 20%. Algal biomass was calculated by a volumetric technique, based on the cell size and shapes the most similar to specific geometric shapes, using the published literature [8].

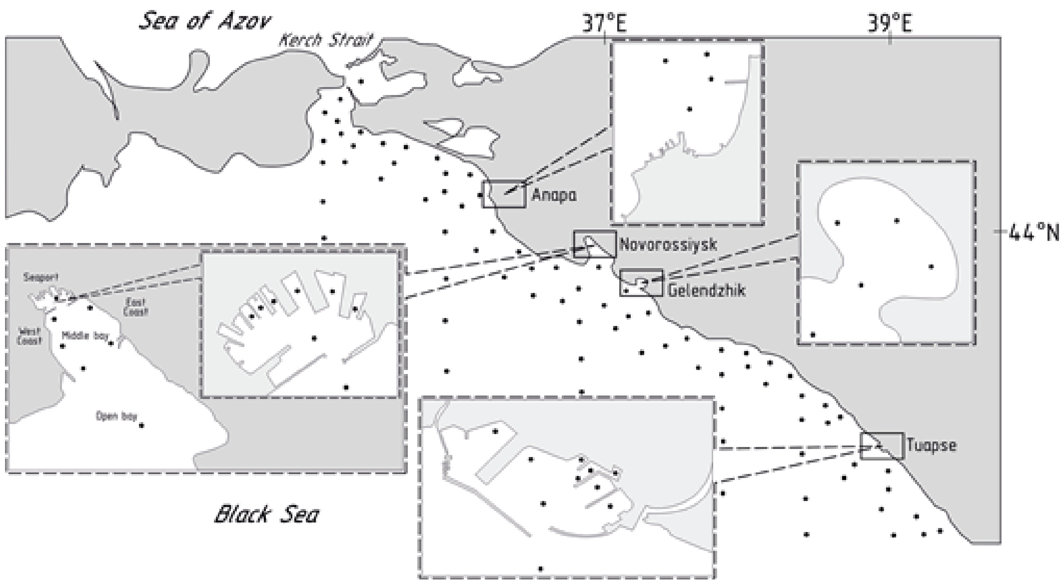

Figure 1: Map of the northeastern Black Sea showing oceanographic stations (dots) where phytoplankton was sampled in 2005-2011.

Due to the fragility of many nanoplanktonic and microplanktonic algae, cells were counted before fixation. Larger cells and rare species were counted in an aliquot (1/5-1/10 of the concentrated samples). Specialized literature was used for species identification [9-11]. The nomenclature was checked and updated according to the AlgaeBase.org website (http://www.algaebase.org/search/species/).

3. Results

3.1. Taxonomic composition of phytoplankton

In total, 210 planktonic algal species were found, belonging to Bacillariophyceae (78 species), Dinophyceae (96), Prymnesiophyceae (5), Cryptophyceae (3), Chrysophyceae (1), Dictyochophyceae (2), Ebriaphyceae (1), Euglenophyceae (6), Chlorophyceae (7), Prasinophyceae (1), Ulvophyceae (1), Pyramimonophyceae (1), Chlorodendrophyceae (1), and Cyanobacteria (7). Similarity of species composition (Sørensen-Czekanowski-Dice index, Cs) between the explored bays and the open NEBS was

75%. The diatom species richness in the bays was 28 species higher than in the open sea, mainly due to the presence in the bay's plankton of neritic species of the genus *Chaetoceros* (8 species) and tychoplanktonic diatom species (15) of the genera *Amphiprora* (2 species), *Achnanthes* (2), *Trieres* (1), *Grammatophora* (2), *Licmophora* (3), *Navicula* (1), *Synedra* (3) and *Petrodictyon* (1). At the same time, a truly oceanic species of diatom *Planktoniella sol* was found only in the offshore area. A significant number of dinoflagellates species (21), mainly the genera *Protoperidinium, Torodinium, Oxytoxum* and *Amphidinium* occurred only in the offshore area, while the other 11 predominantly neritic species of the genera *Protoperidinium, Dinophysis, Protoceratium, Karenia* and *Gymnodinium* were observed only in bays. The planktonic coccolithophorids *Acanthoica acanthos* and *Syracosphaera cordiformis* and the prymnesiophycean *Calyptrosphaera oblonga* occurred only offshore. At the same time, as is typical for coastal areas of low salinity seas, species of Chlorophyceae (freshwater *Scenedesmus* and *Ankistrodesmus* spp.), Cyanobacteria (*Microcystis*) and Prymnesiophyceae (*Phaeocystis*) were present in the outer parts of the bays.

From 1998 until 2010, many species new to the region were found in the NEBS phytoplankton, including the diatoms *Asterionellopsis glacialis* and *Lioloma pacificum*, the dinoflagellates *Dinophysis odiosa* and *Alexandrium ostenfeldii*, and the prymnesiophycean *Phaeocystis pouchetii* [12]. These species had been observed earlier in the northwestern Black Sea and the Bosphorus Strait area since the 1940s. It should be noted that most of the species listed above (except for *Asterionellopsis glacialis* and *Alexandrium ostenfeldii*) did not form a stable population; after 2006-2008, their abundance declined sharply, and later they completely disappeared. Nineteen potentially toxic and harmful species of planktonic algae were found in Novorossiysk Bay, including Dinophyceae (16 species), Bacillariophyceae (2) and Prymnesiophyceae (1) [13].

Abundance and biomass of phytoplankton. The highest phytoplankton abundance and biomass observed in the Novorossiysk port waters (5.10×10^5 cells/L and 1.08 g/m^3). Abundances in Anapa Bay were 1.65×10^5 cells/L and 0.52 g/m^3, and in Gelendzhik Bay --2.04×10^5 cells/L and 0.54 g/m^3, respectively; the values were two-three times less than near Novorossiysk. The minimum value of phytoplankton abundance was observed near Tuapse (1.05×10^5 cells/L and 0.23 g/m^3) and was one-fifth of the values found in the Novorossiysk port. The reduction in the abundance of planktonic algae was observed in the open part of Novorossiysk Bay (3.03×10^5 cells/L), i. e. 1.7 times less than that of the port, although the biomass remained at the same level (1.07 g/m^3). The abundance and biomass of phytoplankton outside the Tuapse port was, respectively, 1.2 and 2 times higher than in the port (1.20x10^5 cells/L and 0.51 g/m^3). The abundance and biomass in the open sea in front of Anapa and Gelendzhik were 1.5-2 times higher than those observed in the bays adjacent to these cities. This increase in abundance of phytoplankton in the open sea was due to the development of the prymnesiophycean *Emiliania huxleyi*; the increase in biomass was mainly due to the dominance of large-celled species of diatoms and dinoflagellates (Figure 2). During a year, three or four peaks of abundance were usually noted. These were observed in different periods of the growing season: late spring, early and/or late summer and autumn.

The dominant species in the bays and port waters belonged to diatoms, which formed on average 60% (range: 47-78%) of the total phytoplankton abundance and 68% (63-78%) of the biomass (Fig.3). Dinoflagellates contributed 15% of the phytoplankton abundance and 27% (15-34%) of the biomass. A minor part of the population consisted of prymnesiophyceans 10% (4-26%), cyanobacteria 8% (3-25%) and euglenophyceans (4%). The dominant species outside the bays and ports also belonged to diatoms: on average 50% (30-62%) of the abundance and 75% (63-80%) of the phytoplankton biomass. Prymnesiophyceans formed on average 40% (25-65%) of the total abundance. At 22% (19-34%), the share of the Dinophyceae of the phytoplankton biomass was approximately the same as in the bays.

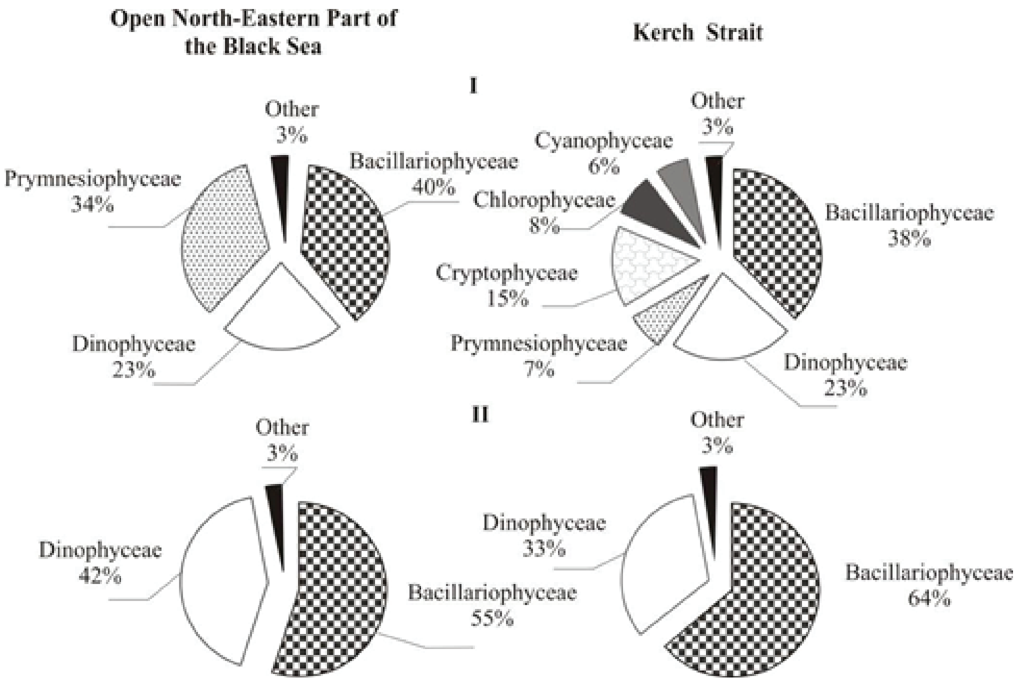

Figure 2: Percentage of the abundance of (I) and biomass (II) of the dominant classes of phytoplankton in the open part of the Black Sea and the Kerch Strait in 2007-2011.

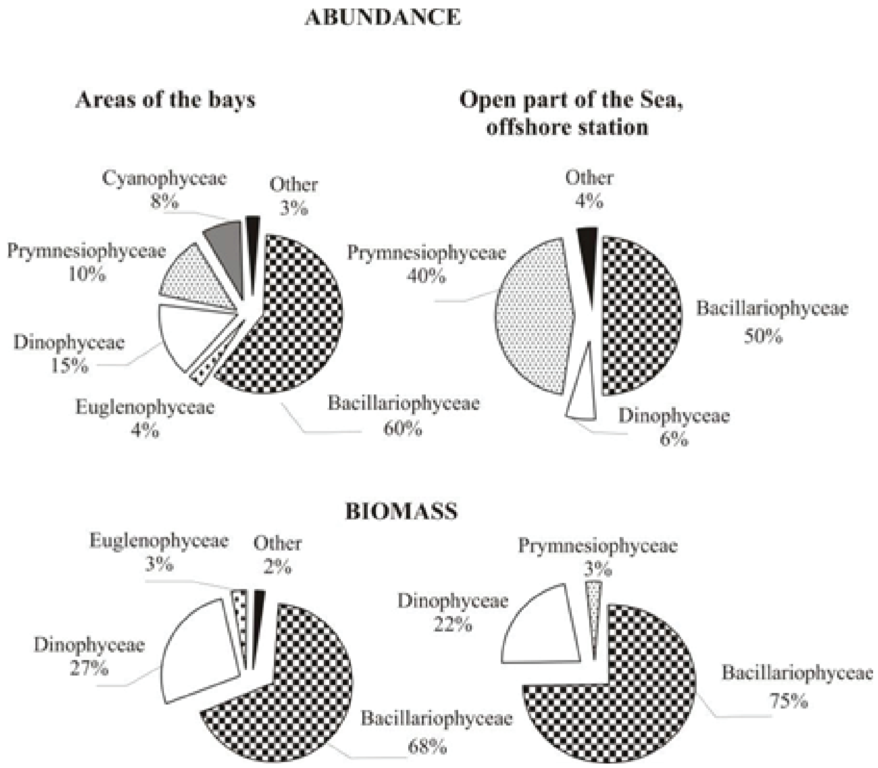

Figure 3: Contribution of individual taxonomic groups in the total abundance and biomass of phytoplankton studied bays and ports and outside in the open part of the Black Sea.

The medium-sized and small-sized diatoms *Cerataulina pelagica, Skeletonema costatum, Chaetoceros curvisetus, C. affinis* and *C. socialis* were dominant numerically in the waters of the studied bays; the subdominant species were *Thalassionema nitzschioides, Leptocylindrus danicus, L. minimus, Proboscia alata*, and *Pseudo-nitzschia* spp. (Fig.4). Small-celled species of *Heterocapsa, Prorocentrum, Gymnodinium, Gyrodinium* and *Scrippsiella* dominated numerically among dinoflagellates. The dominant complex outside the bays consisted of the same species of diatoms and dinoflagellates as in the bays, except for the mesosaprobic *Skeletonema costatum*, *Leptocylindrus* and *Heterocapsa* spp.; the shares of *Dactyliosolen fragilissimus, Nitzschia tenuirostris*, *Chaetoceros* spp. (45% of the diatom cell abundance), and *Protoperidinium* spp. (12 % of dinoflagellate abundance) were major [14].

The bulk of diatom biomass in harbours and ports was made up of *Cerataulina pelagica, Proboscia alata, Pseudosolenia calcar-avis* and *Chaetoceros* spp. (Fig.5). Among dinoflagellates, large-celled *Ceratium* and medium-sized *Scrippsiella* and *Prorocentrum* spp. were dominant in biomass. In the open sea, just outside the bays and ports, the roles of large diatoms *P. calcar-avis, P. alata, D. fragilissimus* and dinoflagellates *Protoperidinium* spp. were significantly greater in biomass. The biomass of *Cerataulina pelagica* and that of *Prorocentrum* spp decreased by factors of 1.5-2.

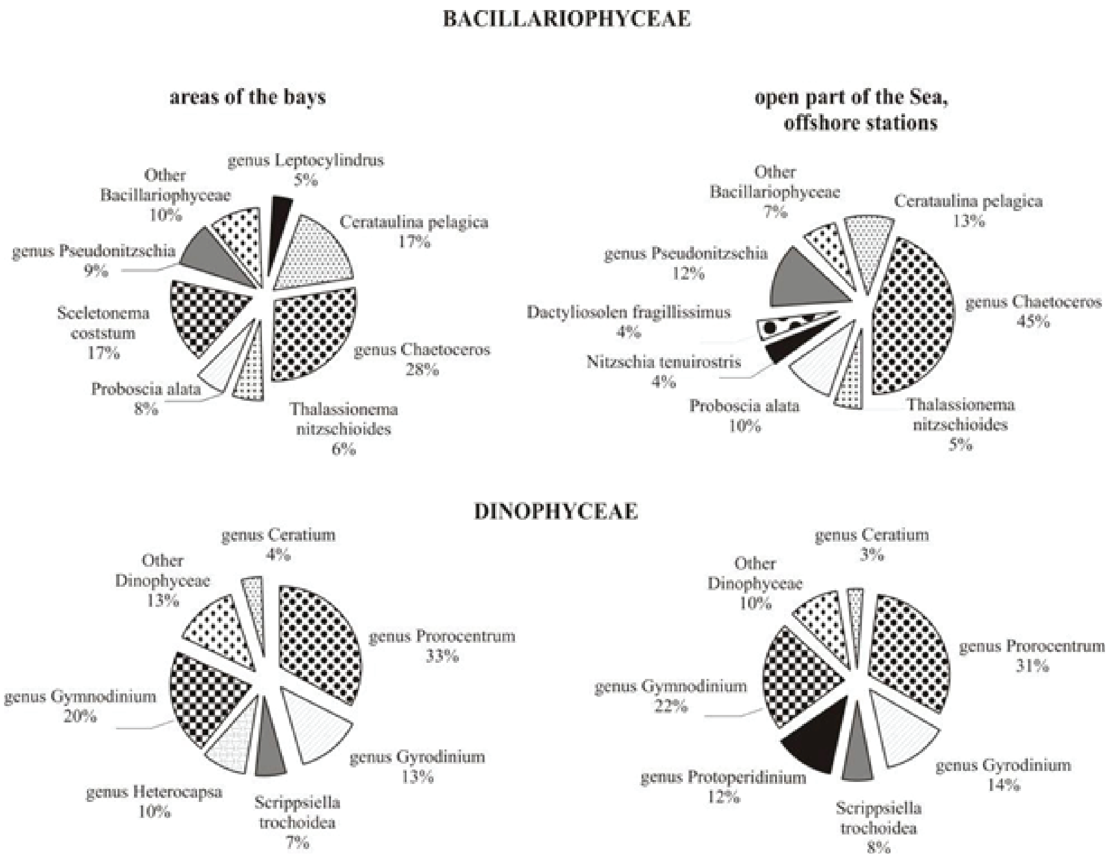

Figure 4: The contribution of individual species in the total abundance of phytoplankton studied bays and ports and outside in the open part of the Black Sea.

From 2007-2011, the mean values of the abundance and biomass of phytoplankton in the open NEBS reached $5.40x10^4$ cells/L and 0.28 g/m^3, respectively. The largest contributions, both in abundance (40% and 23%) and biomass (55% and 42%) of phytoplankton of the open NEBS, were made by diatoms and dinoflagellates, respectively. Prymnesiophyceans, the main species of which was nanoplanktonic *Emiliania huxleyi*, formed a significant portion (34%) of the total phytoplankton abundance. The maximum share (up to 74% of phytoplankton abundance) of *E. huxleyi* was observed in July 2007, June 2008 and April 2009.This species preferred the upper 20 m of the water column.

Seasonal succession of phytoplankton in open waters was followed, first in the dominant species. The small-celled diatoms *Chaetoceros insignis, Nitzschia tenuirostris* and *Chaetoceros* sp. and the dinoflagellate *Scrippsiella trochoidea* increased in biomass in April 2008 and 2009. The small-celled prymnesiophycean *E. huxleyi* and the diatoms *Pseudo-nitzschia* cf. *pseudodelicatissima* and *Pseudosolenia calcar-avis* dominated in June 2008. Intensive development of the large-celled diatoms (up to 63% and 27% of the phytoplankton abundance) *P. calcar-avis, P. alata, Dactyliosolen fragilissimus* and dinoflagellates *Ceratium tripos, C. furca, Protoperidinium divergens* and *Protoceratium*

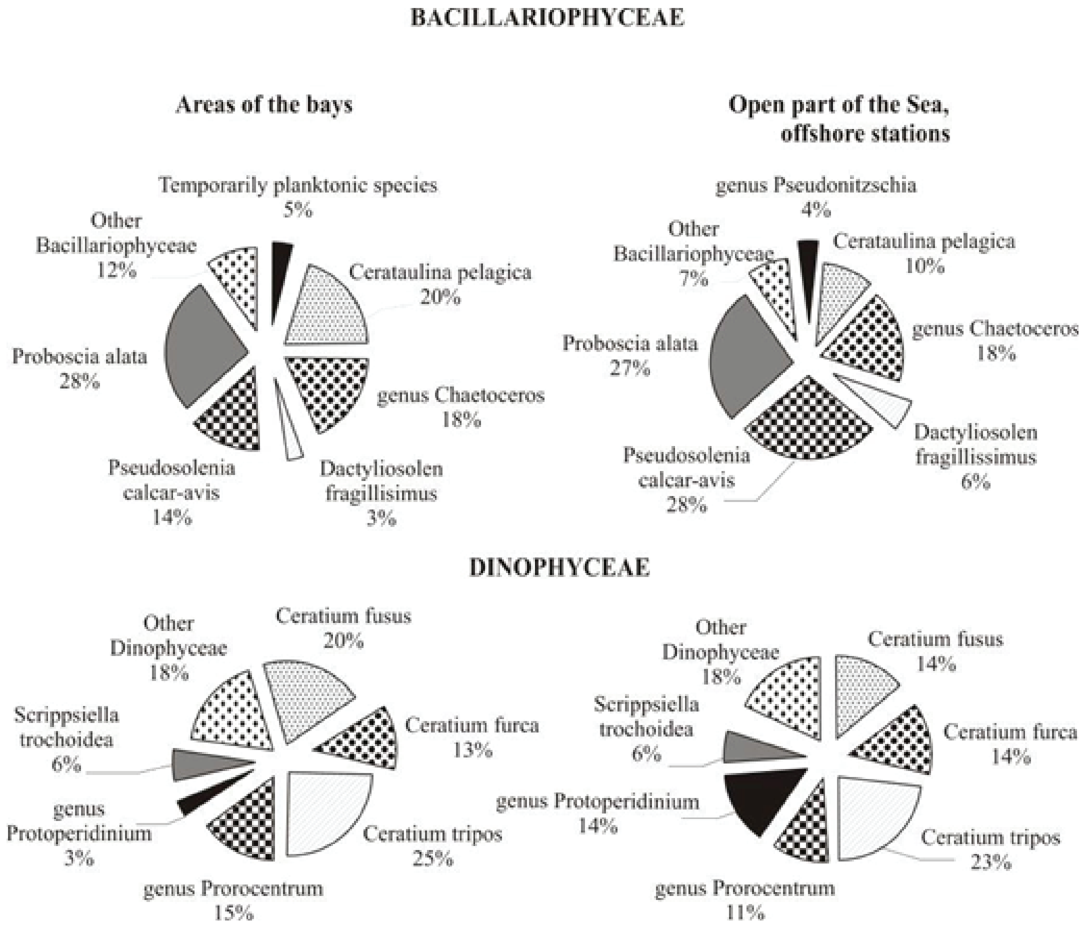

Figure 5: The contribution of individual species in the total biomass of phytoplankton exploration bays and ports and outside in the open part of the Black Sea.

reticulatum was observed in October 2008. Due to the dominance of large-celled species, phytoplankton biomass values in summer (393 mg/m^3) and autumn (515 mg/m^3) were more than twice the spring values. The basic habitat of the planktonic algae was in the upper 30 m layer where both the abundance and biomass were highest. Phytoplankton concentration decreased sharply with depth (only 10-20% of the surface values at the 50 m isobath). Phytoplankton abundance along the coastal area exposed to the open sea was 2-3 times higher than that observed at deep-water stations. Intensive processes of vertical water convection in the coastal zone appeared to contribute to more uniform vertical distribution of phytoplankton. Diatoms and prymnesiophyceans usually dominated near the sea surface. The role of the large-celled dinoflagellates in the biomass significantly increased with depth.

The abundance of planktonic algae (9.8x10^4 cells/L) observed in the Kerch Strait from 2009-2011 was almost twice as high as that found in the open NEBS during the same period. Due to the development of small-sized species, the phytoplankton biomass in the Kerch Strait (0.186 g/m^3) was about 1.5 times less than that in the study area in the Black Sea. Diatoms contributed 38% of the phytoplankton abundance and 64% of the phytoplankton biomass. *Skeletonema costatum, Chaetoceros curvisetus, Ditylum brightwellii, Nitzschia tenuirostris, Thalassionema nitzschioides, Pseudosolenia calcar-avis, Cyclotella caspia*, *Coscinodiscus, Striatella* and *Gyrosigma* spp. were dominant. Dinoflagellates contributed 23% of the phytoplankton abundance and 33% of the phytoplankton biomass. *Oxyrrhis marina, Prorocentrum micans, Oblea baculifera, Scrippsiella acuminata, Akashiwo sanguinea*, *Gymnodinium* and *Gyrodinium* spp. were the most numerous among them. Abundance of *Prorocentrum* spp., *Gyrodinium fusiforme* and *Kapelodinium vestifici* increased near the bottom. Most of the biomass was formed by the medium-sized dinoflagellates *Dinophysis fortii, Protoperidinium divergens, Diplopsalis lenticula* and *Polykrikos kofoidii*. There was a significant contribution of some green algal species (*Binuclearia lauterbornii* and *Monoraphidium contortum*), cyanobacteria (the genera *Oscillatoria, Lyngbya, Amphanisomenon* and *Synechocystis*), prymnesiophyceans (*Emiliania huxleyi*) and cryptophyceans (*Plagioselmis prolonga, Plagioselmis punctata*) in the Kerch Strait. The species of these major taxonomic groups formed 8%, 6%, 7% and 15 % of the total phytoplankton abundance, respectively.

4. Discussion

Taxonomic composition of phytoplankton in the NEBS comprised 210 species. A greater variety of neritic diatoms and dinoflagellates was found in bays. Marine oceanic dinoflagellates and prymnesiophyceans dominated in the open sea.

High abundances of phytoplankton, with the predominance of small-sized mesosaprobic diatoms (*Skeletonema costatum, Leptocylindrus minimus, L. danicus, Thalassionema nitzschioides* and *Chaetoceros* spp.), euglenophyceans (*Eutreptia lanowii*), cyanobacteria (*Lyngbya* and *Oscillatoria* spp.) and mixotrophic dinoflagellates (*Gymnodinium, Gyrodinium, Heterocapsa* and *Prorocentrum* spp.) were found in the bays.

Beyond the ports and bays, the majority of the phytoplankton population (34-40%) belonged to the nanoplanktonic prymnesiophycean *Emiliania huxleyi*. In open waters of the NEBS, a significant share of the phytoplankton biomass (45%) was due to the large-celled microplanktonic diatoms *Proboscia alata* and *Pseudosolenia calcar-avis* and to the dinoflagellates *Protoperidinium* spp.

Within the period 2007-2011, long-term phytoplankton dynamics revealed a decrease in abundance in bays; the same phenomenon occurred in the open sea in 2009 and 2011.

Five species new to the area were recorded in the NEBS phytoplankton: the diatoms *Asterionellopsis glacialis* and *Lioloma pacificum*, the dinoflagellates *Dinophysis odiosa* and *Alexandrium ostenfeldii,* and the prymnesiophycean *Phaeocystis pouchetii.* Previously, these species had been found exclusively in the northwestern Black Sea and the Bosphorus Strait area.

Nineteen phytoplankton species of the following genera found in the Novorossiysk Bay are potentially toxic and harmful: diatoms (*Pseudo-nitzschia*), dinoflagellates (*Alexandrium, Prorocentrum, Dinophysis, Scrippsiella, Ceratium, Lingulodinium* and *Akashiwo*), and prymnesiophyceans (*Phaeocystis*). The period of high risk associated with the intensive growth of these species falls in the warm season (April-August).

5. Conclusion

Thus, the monitoring of the phytoplankton for duly detection and diagnostics of the "plankton bloom" caused by development of potentially toxic species, policy of ballast water control and management promote to the prevention of biologically hostile invader introduction by marine transport and conservation of the Black Sea natural biodiversity.

Funding

This study was possible due to the program № AAAA-A18-118122790121-5.

Acknowledgement

The authors are grateful to Academician RAS G.G. Matishov and Corresponding Member of the RAS, D.G. Matishov for the opportunity to carry out scientific work; to O.V. Stepanyan (Southern Scientific Centre, Russian Academy of Sciences), G.V. Kovaleva (Institute of Arid Zones, Southern Scientific Centre, RAS), J.P. Selifonova (Admiral Ushakov State Maritime University, Novorossiysk, Russia), E.B. Goldin (V.I. Vernadsky Crimean Federal University, Simferopol, Russia), Y.I. Sorokin, L.A. Pautova (P.P. Shirshov Institute of Oceanology, RAS), L.M. Terenko, D.Y. Bryantseva (N.G. Kholodnyi Institute of Botany, National Academy of Sciences of Ukraine, Kiev) for their advice and valuable comments, to V.V. Erygin and V.S. Berdnikov (Administration of Sea Ports of the Black

Sea, Novorossiysk, Russia) for logistic support and to Marcia M. Gowing (University of California at Santa Cruz, California, USA) for improving the English style.

Conflict of Interest

The authors have no conflict of interest to declare.

References

[1] Kreneva, S.V. (2002). Application of the principle of succession analysis to assess and predict the status of aquatic ecosystems. PhD Dissertation, Moscow.

[2] Chasovnikov, V. K., Yakushev, E. V., et al. (2011). Variability of nutrients in the Black sea coastal zone. *Integrated studies of the Black sea,* pp. 255-268.

[3] Sorokin, Y.I. (1979). *To the method of concentrating of phytoplankton*. Gidrobiol. Log. 2, P. 71-76. (In Russian).

[4] Tsyban, A.V. (1980). *A guide to the methods of biological analysis of sea water and bottom sediments.* L: Gidrometeoizdat, 191 p. (In Russian).

[5] Sukhanova, I.N. (1983). The concentration of phytoplankton in the sample. In: ed Vinogradov M.E. *Modern methods of quantitative assessment of marine plankton distribution.* M: Nauka, pp. 97-105. (In Russian).

[6] Makarevich, P.R., Druzhkov, N.V. (1989). *Guidelines for the analysis of quantitative and functional characteristics of the marine biocenoses of the Nordic Seas. Part 1. Phytoplankton. Zooplankton. Suspended organic matter.* Marine Biological Institute, Kola Scientific Centre, Russian Academy of Sciences, Apatity, Murmansk, 50 p. (In Russian).

[7] Radchenko, G.I., Kapkov, V.I., Fedorov, V.D. (2010). *Practice manual for the collection and for analysis of marine phytoplankton sampling.* M: Moscow State University. 60 p. (In Russian).

[8] Bryantseva, J.V., Lyakh, A.M., Sergeeva, A.V. (2005). *Calculation of volumes and surface areas of the Black Sea unicellular algae.* National Academy of Sciences of Ukraine, Institute of Biology of the Southern Seas, Sevastopol. 25 p.

[9] Proshkina -- Lavrenko, A.I. (1955). *Plankton diatoms of the Black Sea.* USSR ACADEMY OF SCIENCES. 216 p. (In Russian).

[10] Dodge, J. D. (1982). *Marine dinoflagellates of the British Isles.* London: HMSO. 301 p.

[11] Tomas, C.R. (ed.). (1997). *Identifying marine phytoplankton.* San Diego, CA. Academic Press. Harcourt Brace Company. 821 p.

[12] Yasakova, O. N. (2011). New Species of Phytoplankton in the Northeastern Part of the Black Sea. *Russian Journal of Biological Invasions,* vol. 2, No. 1, pp. 65--69.

[13] Yasakova, O. N. (2013). The Seasonal Dynamics of Potentially Toxic and Harmful Phytoplankton Species in Novorossiysk Bay (Black Sea). *Russian Journal of Marine Biology,* vol. 39, No. 2, pp. 107--115.

[14] Yamada, M., Tsuruta, A., Yoshida, Y. (1980). List of phytoplankton as eutrophic level indicator. *Bull. Jap. Soc. Sci. Fish.* vol. 46, № 12. pp. 1435--1438.